

MINIATURIZED ANTENNA ELEMENT AND ARRAY

FIELD OF THE INVENTION

The present invention relates generally to the field of commercial antenna development for wireless internet services.

ABSTRACT

The invention consists of reduced size dipole and monopole antennas, printed on one side of a substrate with slotted loading patches at the end(s) of the antenna, and a conducting strip on the reverse side to form a folded dipole or monopole structure. The size of the structure is approximately half that of a conventional printed dipole or monopole, while maintaining or increasing the useful bandwidth. The antennas can be used in conjunction with simplified reflector and director elements to form Yagi-Uda arrays, as well as larger broadside arrays consisting of a number of Yagi-Uda arrays operated in conjunction to form a narrow fan beam. The arrays offer improved appearance due to reduced size, simpler mounting, and greater ease in alignment compared to arrays commonly in use for wireless networking.

BACKGROUND OF THE INVENTION

The range and data rate of wireless internet services, as well as other forms of wireless data communications, depend on power, antenna gain, and signal bandwidth, among other factors. All three factors are limited both by economic and size considerations; furthermore, in the most commonly used frequency bands for unlicensed wireless internet services in the US, the 2400-2483.5 MHz ISM (industrial, scientific, and medical) band, as well as in the other unlicensed bands (e.g. 5725-5850 MHz), the transmitter power, transmitting antenna gain, and signal bandwidth are all directly or indirectly limited by federal regulations (Title 47, Part 15, Sec 15.247).

Current regulatory limits for point-to-multipoint communications (e.g. the base to client link when a base serves multiple clients) in the above mentioned bands require spread spectrum operation covering most of the frequency band, and an EIRP (effective isotropic radiated power) of no more than 36 dBm with a transmit power of no more than 30 dBm. Thus systems taking full advantage of the allowable parameter range need an antenna gain of at least 6 dBi. Systems with lower power transmitters need a higher antenna gain, for example, a 20 dBm transmitter is best operated a 16 dBi antenna. Current commonly used solutions for low gain (6-12 dBi) antennas in the ISM band are collinear verticals and corner reflector antennas. Common medium gain antennas (12-20 dBi) are arrays of dipoles and patches, with or without corner reflectors or backplates. For high gain antennas (> 20 dBi) parabolic reflectors are almost exclusively used.

The option of reduced transmit power with increased gain is desirable from a point of view of interference reduction, and also reduces the transmitter/power amplifier

cost. On the other hand, end users generally find smaller antenna size desirable, both for appearance, mounting, and safety concerns. Furthermore, lower gain antennas are simpler to align and less critical in their mounting accuracy.

The present invention addresses the need for antennas with reasonably high gain (12 to 24 dbi) that have reduced size, both in terms actual volume and in visual size as perceived from a distance, and greater ease in alignment and mounting, while still covering the entire required frequency range. Since electromagnetic principles show that smaller antennas generally have smaller gain and reduced bandwidth, innovative design techniques are needed to achieve a size reduction without impacting performance.

Furthermore, for a particular value of antenna gain, a fan beam with a narrow beamwidth in the horizontal plane and a relatively broad beamwidth in the vertical plane is desirable for three reasons. First, interference sources/receptors have a tendency to appear distributed along the horizon as seen from the antenna. A narrow beamwidth in the horizontal plane will have significantly improved ability to discriminate between interference sources/receptors and the desired link, while the broad vertical beamwidth will sacrifice little in this respect. Second, having a broad beam in one plane means that accurate pointing is necessary only in the other plane. Thus, a greatly simplified mounting structure with only one degree of freedom is possible, improving both cost and rigidity. Third, since only one degree of freedom is available in the mounting initial alignment when the antenna is installed is simplified.

The present invention employs techniques including antenna folding, dielectric loading and end loading in a printed circuit format in order to reduce the size of the antenna, in particular the height when used as a vertical polarization radiator. The gain is achieved by employing both Yagi-Uda and broadside array techniques. The array configuration also yields a beam that is narrower in the horizontal plane than in the vertical plane. The combination of reduce size, ease of mounting, and interference reduction should be attractive and useful, particularly for client stations in a situation where multiple clients communicate with a base station.

SUMMARY OF THE INVENTION

It is one object of the invention to provide a low profile, reduced size antenna.

It is another object of the invention to provide reduced size dipole and monopole antennas, printed on one side of a substrate with slotted loading patches at the end(s) of the antenna, and a conducting strip on the reverse side to form a folded dipole or monopole structure.

It is another object of the invention to provide linear and/or broadside Yagi-Uda arrays of reduced size elements to form a directional antenna, with narrow beamwidth in one plane and broader beamwidth in another plane.

DETAILED DESCRIPTION OF THE INVENTION

1. The first component to be described is a reduced size printed dipole antenna element, as depicted in Figures 1 and 2. Figure 1 depicts the front side of the element, and Figure 2 depicts the reverse side. The reduced size printed dipole antenna element consists of a dielectric substrate (7), with patterned metallized regions (8) which can be formed by any of the processes commonly used to form printed circuits. The metallized regions on the front side form a linear, driven conductor (30) with a feed point (40) at the center, as well as end loading patches (20). Slots (50) are cut into the end loading patches in order to effectively extend the length of the linear driven conductor. Although the patches are shown as being rectangular in shape, similar performance can be obtained with other shapes, for example, round. The loading patches have the effect of lowering the first resonant frequency of the antenna for a given length; or, conversely, reducing the length required to obtain resonance at a given frequency. However, this length reduction, if used alone, tends to reduce the radiation resistance of the antenna, leading to poor impedance match and lower efficiency. It also decreases the bandwidth. These effects can be compensated by the placement of a second, linear, undriven conductor (33) on the reverse side of the substrate, connected to the driven conductor through vias holes (10) in the substrate. In the preferred embodiment, the via hole connections are at the ends of the antenna, to form a folded dipole. In other embodiments the position of the holes could be moved to another position along the antenna to modify the impedance. The folding effected as described increases the input impedance, and thus the radiation resistance. If the strips are of equal width the radiation resistance increases by a factor of four; by varying the widths different multiplication factors can be obtained. The strips also form a parallel strip transmission line with dielectric loading due the substrate. The dielectric has the effect of reducing the velocity of the transmission line. By proper selection of the dielectric constant and length of the antenna, the transmission line can be made antiresonant at the same frequency at which the antenna structure is resonant. The combination of the antiresonance and resonance allows the antenna to have a double-tuned response, and a bandwidth greatly improved over a simple resonant response.

In a typical design for operation at 2.45 GHz, the length of the antenna is 1.2 inches, the width of the conducting strip is 0.16 inches, the patch measures 0.4 inches by 0.5 inches, and the slots are 0.02 inches wide by 0.16 inches long. The substrate is 0.031 inches thick with a dielectric constant of 4.7. However, modification of these dimensions is clearly possible to suit various applications; in particular, the design can be easily scaled to any operating frequency using formulas available in textbooks and known to skilled practioners. The antenna is typically half the length of a conventional antenna at this frequency.

2. The second component to be desribed is a reduced size printed monopole antenna element based on the same principles, the front side of which is depicted in Figure 3. It is identical to the reduced size printed dipole antenna element described above except that only half of the structure is used, and this half is mounted over a conducting ground plane (5), with plane of the antenna substrate (7) perpendicular to the conducting ground plane. The driven element (30) can be excited by a conductor (90) fed through the ground plane.

The undriven element on the reverse side is connected directly to the ground plane. Again, by varying the relative widths of the two conducting strips the impedance level can be adjusted, and by proper selection of the antenna length in combination with the dielectric constant of the substrate a broad double-tuned response can be obtained.

3. The third component to be described is a parasitic (also known as passive) reduced size printed dipole antenna element, the front side of which is depicted in Figure 4. The element is identical to the reduced size printed dipole antenna element described in part 1 above described above and shown in Figures 1 and 2, except that the second undriven conductor, the feed point, and the via holes are omitted. The reverse side needs no metallization and can be left completely bare of metal. A number of these parasitic reduced size printed dipole antenna elements can be used in conjunction with the reduced size printed dipole antenna element described in part 1 above and shown in Figures 1 and 2, to form Yagi-Uda type arrays, as will be described below. For use as a passive reflecting element, the length is increased (typically by about 10 to 15%) over the length used in the driven element. For use as a passive directing element, the length is decreased (typically by about 10 to 15%) below the length used in the driven element.

4. The fourth component to be described is a parasitic (also known as passive) reduced size printed monopole antenna element. The element is identical to the reduced size printed monopole antenna element described in part 1 above described above and shown in Figures 1 and 2, except that the second undriven conductor, the feed point, and the via holes are omitted. The conducting element is connected directly to the ground plane. The reverse side needs no metallization and can be left completely bare of metal. A number of the parasitic reduced size printed monopole antenna elements can be used in conjunction with the reduced size printed monopole antenna element described in part 2 above and shown in Figure 3, to form Yagi-Uda type arrays, as will be described below. For use as a passive reflecting element, the length is increased (typically by about 10 to 15%) over the length used in the driven element. For use as a passive directing element, the length is decreased (typically by about 10 to 15%) below the length used in the driven element.

5. The fifth item to be described is a Yagi-Uda type array formed from combinations of the elements described in the previous paragraphs. In the same manner as conventional dipoles and monopoles, the reduced size printed antenna elements described above can be combined in antenna arrays of any type, using methods that are familiar to skilled practitioners.

In one embodiment of the invention, depicted in Figure 5, the elements of the array are coplanar and can be conveniently printed on a single substrate (7). An enlarged version of the parasitic reduced size printed dipole element described in part 3 above is used as a reflecting element (3a), while one or more smaller versions of the same element are used as director elements (3b). A reduced size printed dipole element as described in part 1 above is placed between the reflecting element and the director elements and is used as the driven element (5). The spacing between the elements is typically about 0.2 wavelengths. The spacing can be varied in conjunction with the lengths of the reflector and director elements in order to adjust the gain, pattern, and

frequency response of the antenna. Performance substantially comparable to conventional Yagi-Uda arrays is obtained, with a narrow beam radiated along the array axis in the direction of the director element and reduced radiation in the direction of the reflector element. A front-to-back ratio of 15 dB can be readily obtained.

In another embodiment, depicted in Figure 6, the elements are printed on separate substrates transverse to the array axis. Both configurations can yield a directive pattern with good front-to-back ratio.

It should be noted that both of the embodiments of the Yagi-Uda array can be implemented effectively using the monopole versions of the driven and parasitic elements, as described in parts 2 and 4 above.

6. The sixth item to be described is a broadside array formed from combinations of the elements described in the parts 1 through 4. A typical embodiment is shown in Figure 7, and consists of a number of driven reduced size printed dipole antenna elements (5) as described in part 1 positioned on a single substrate (7a). In the preferred embodiment the elements are spaced equally, typically with a spacing of not less than one-quarter and not more than one-half wavelength; however, unequal spacings and spacings outside the typical range may be used.

A method for feeding the broadside array is depicted in Figures 8 and 9, with Figure 8 showing an overall view and Figure 9 a cross section detail. A second substrate (7b) is mounted perpendicular to the first substrate (7a), and has formed on it a metallized pattern of parallel strip transmission lines (70), that is, transmission lines with strips facing each other on either surface of the substrate. In the preferred embodiment, narrower and thus higher impedance transmission lines (72) are used to feed the outer elements and wider and thus lower impedance transmission lines (75) are used to feed the inner elements. By proper selection of the widths the impedances can be arranged such that substantially equal power is distributed to each element in the broadside array, and by proper selection of the line lengths, taking into account the dielectric constant of the substrate material (7b), the drive to each element can be made to be substantially in phase; the combination of equal power and phase giving high gain broadside radiation. By slight modifications of the widths, a tapered amplitude distribution can also be obtained to reduced sidelobe levels at the cost of reducing the gain. At the center, a perpendicular feed line (78) is added to step the overall impedance up to a level suitable for feeding from standard coaxial cables, using a connector mounted at a feed point (60). The transmission lines (72) and (78) are connected to the feed points of the driven elements (5) at the point where the antenna substrate (7a) and feed substrate (7b) join, typically though solder joints at the junctions, although any electrical connection type may be used.

The broadside array will yield a vertical fan-beam radiation pattern that is much more narrow in the horizontal plane than in the vertical plane. This will ease mounting and alignment difficulties in usage of antennas in applications such as client side radios in wireless networks, since the antenna mount only needs precision adjustment in one plane. Thus the antenna could be mounted on a simple pole that could be rotated to point it towards a base station. In a typical embodiment with four elements both substrates (7a) and (7b) have dielectric constant of about 4.0 and the spacing of the elements is approximately 0.5 free space wavelengths, with the narrower lines (72) having a